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THESIS

DESIGNING A STANDARD MODEL FOR DEVELOPMENT AND EXECUTION OF AN ANALYSIS PROJECT PLAN

by

Leslie T. Willis

June 2012

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13. ABSTRACT (maximum 200 words)

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Having such a plan is important to the OS&A branch and ARDEC as a whole because it documents decisions, facilitates communication among stakeholders, and maintains a record of scope, cost, and schedule baselines. By instituting a standardized process, the OS&A branch would ensure that results based on the Analysis Project Plan are reusable, allow for configuration management, better management of overall resources, and better validation and verification.

Through Systems Engineering principles, personal observations, team collaboration, and other considerations, the process proposed in this thesis has been developed for the Analysis Project Lead to improve his or her ability to systematically accomplish the job. Ultimately, the proposed process's intent is to establish a flexible process where communication of the problem is precise, the magnitude of the solution is relevant and reliable, and the tools and personnel to execute the analysis are employed at the right times.

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DESIGNING A STANDARD MODEL FOR DEVELOPMENT AND EXECUTION OF AN ANALYSIS PROJECT PLAN

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requirements for the degree of

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LIST OF ACRONYMS AND ABBREVIATIONS

APO	ARDEC Project Officer
ARDEC	Armaments Research, Development, and Engineering Center
CCB	Configuration Control Board
CM	Configuration Manage / Configuration Management
ConOps	Concept of Operations
DAU	Defense Acquisition University
HLD	Homeland Defense
HW, H/W	Hardware
IRD	Interface Requirements Document
MOE	Measure of Effectiveness
MOO	Measure of Outcome / Measure of Operation
MOP	Measure of Performance
NASA	National Aeronautics and Space Administration
NT	Network
ODSA	Operational Distributed Simulation and Analysis
ORSA	Operations Research, Systems Analysis
OS&A	Operational Simulation & Analysis
POC	Point of Contact
PRD	Performance Requirements Document, Project Requirements Document
R&D	Research & Development
RDECOM	Research, Development, and Engineering Command
ROI	Return on Investment
SE	Systems Engineer
SME	Subject Matter Expert
SOI	System of Interest
SRD	System Requirements Document
SW, S/W	Software
TPM	Technical Performance Measurement / Measure
TTP	Tactic, Techniques, and Procedures

V&V	Verification & Validation
WBS	Work Breakdown Structure / Schedule

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First and foremost, I am indebted to my country and the war fighter for ensuring me the freedom to live in a land where I can pursue my dreams. To wit, I also thank my interpretation of God—the mystery with whom we all stand before—for giving me purpose, guidance, and wisdom throughout my life.

I wish to express my deepest gratitude to Fran Luzzi, former Chief of the Operational Simulation and Analysis Branch, Ingrid Dombroski, Competency Manager of the System Analysis Division, Matt Cilli current Chief of the Operational Simulation and Analysis Branch, and Jeff Dyer, Director of the Systems Engineering Directorate at RDECOM-ARDEC, Picatinny Arsenal, for providing their guidance and support. Through their acts, they have emphasized their commitment to continuous learning and betterment of self in order to achieve and sustain the best workforce in support of the war fighter.

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So much love and thanks are owed to my parents for their support and encouragement. They set the groundwork and succeeded in instilling the appreciation of just how profound the value of a higher education is in me.

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It is to my children, Ashley, Caleb, and Tiernan; that I dedicate this thesis.

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I. INTRODUCTION

A. BACKGROUND

Within the Operational Simulation and Analysis (OS&A) branch of the U.S. Army Armament Research, Development, and Engineering Center (ARDEC) at Picatinny Arsenal, there exists no standard process for development and execution of an Analysis Project Plan. A project plan is a formal document which, when agreed upon by parties involved, guides the execution and control of a project. The Analysis Project Plan should leverage the Defense Acquisition University's definition of a Systems Engineering Plan (SEP), which is "A detailed formulation of actions that should guide all technical aspects of an acquisition program" (Defense Acquisition University 2011). The SEP is intended to be a roadmap that supports program management by defining comprehensive systems engineering activities and is prepared for each phase of a Defense Acquisition Framework (Defense Acquisition University 2011).

Specifically, an Analysis Project Plan uses the same processes as the SEP and is further tailored to the expertise of the OS&A branch. Having such a plan is important to the OS&A branch and ARDEC as a whole because it documents decisions, facilitates communication among stakeholders, and maintains a record of scope, cost, and schedule baselines. By instituting a standardized process, the OS&A branch would ensure that results based on the Analysis Project Plan are reusable, allow for configuration management, better management of overall resources, and better validation and verification.

Through systems engineering principles, personal observations, team collaboration, and other considerations, the process proposed in this thesis has been developed for the Analysis Project Lead to improve his or her ability to systematically accomplish the job. Ultimately, the proposed process's intent is to establish a flexible process where communication of the problem is precise, the magnitude of the solution is relevant and reliable, and the tools and personnel to execute the analysis are employed at the right times.

B. ARDEC AND OS&A ORGANIZATIONAL RELATIONSHIP

ARDEC's mission is to provide world class support for the research, development, production, field support and demilitarization ARDEC and RDECOM products. Concurrently, ARDEC also strives to support the RDECOM mission of getting the right technology to the right place, at the right time for the War fighter (U.S. Army ARDEC 2001).

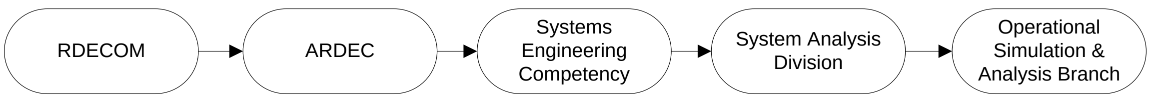

Figure 1. Research, Development & Engineering Command (RDECOM) to the Operational Simulation & Analysis (OS&A) branch Hierarchy

As seen in Figure 1, the Operational Simulation and Analysis (OS&A) branch is a subset of the Armaments Research Development and Engineering Center (ARDEC) under the Systems Engineering Competency and System Analysis Division. The vision of the OS&A branch is to provide a processing & simulation facility which integrates engineering, operational, logistics, and visualization capabilities and products through the use of distributed simulation technologies with the ultimate goal of conducting operational analyses of ARDEC technology concepts. These analyses benefit the war fighter by validating their requirements early in the life cycle and quantifying their benefits. The ultimate intent of the OS&A branch, in support of the ARDEC and RDECOM mission is to aid in providing shorter acquisition cycle times of ARDEC armament products (F. J. Luzzi, personal communication, January 2010).

C. PURPOSE OF A STANDARDIZED PROCESS

Various projects within the OS&A branch have used and provided insight to the need for a standardized process. Currently, a prototype process is being applied to a Homeland Defense (HLD) Project which requires the OS&A branch to provide a simulation environment for the evaluation of ARDEC products (direct requirement from

the customer) with a focus on Disaster Planning & Response (derived requirements from stakeholders and subject matter experts identified by the primary customer).

Collectively, the OS&A branch would like to employ a Systems Engineering process tailored for their specific capabilities. Justification for such a process, as discussed in detail in Chapter II, includes the need for Reuse, Configuration Management (CM), Resource Management, Verification & Validation (V&V), as well as establishing methods to develop accurate time and cost estimates.

Since previous project efforts tend to be applicable to existing and future projects, establishing a configuration management scheme to archive past analyses provides the branch the ability to positively affect cost, schedule, and performance criterion. Additionally, such configuration management processes contribute to the V&V of projects. Through use of a configuration management scheme, Developers, Analysts, Project Leads, and others will be able to review items stored and obtain critical information which supports the managed product's integrity, authenticity, non-repudiation, verification, and validation. Perhaps most important is employing the process to capture subject matter expert feedback on the project while it is in progress. Over time, this process will enable the team to build up a repository of simulation and analysis projects. By doing so, future projects are likely to require shorter lead times given applicable historical analyses conducted.

Finally, use of the process will provide clear definitions of responsibility since not every member in a project has actions at the same time and resource scheduling within the process should reflect this fact. By resourcing the project within process guidelines, management will be able to better manage their resources and will work towards maximizing productivity.

The current proposed process consists of numerous steps grouped into four functional categories: Initiation, Planning, Execution, and Analysis. It is of particular importance to note that the phases stated above were not in the original proposed process. This is because it was not until the original process was put into practice on various

projects that clear phase delineation became apparent thus illustrating the intended fluidity of the process. Figures 2 and 3 depict the evolution of the proposed process over the course of researching this thesis.

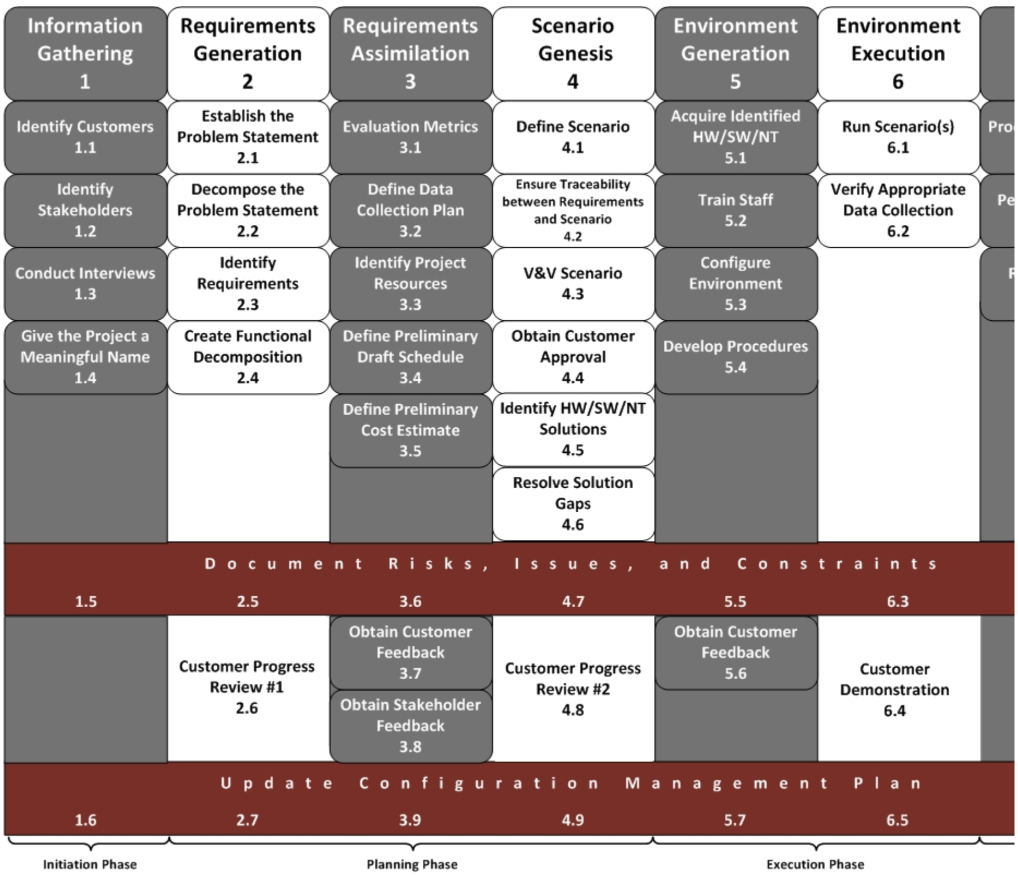

Figure 2. Initial Proposed Architectural Process

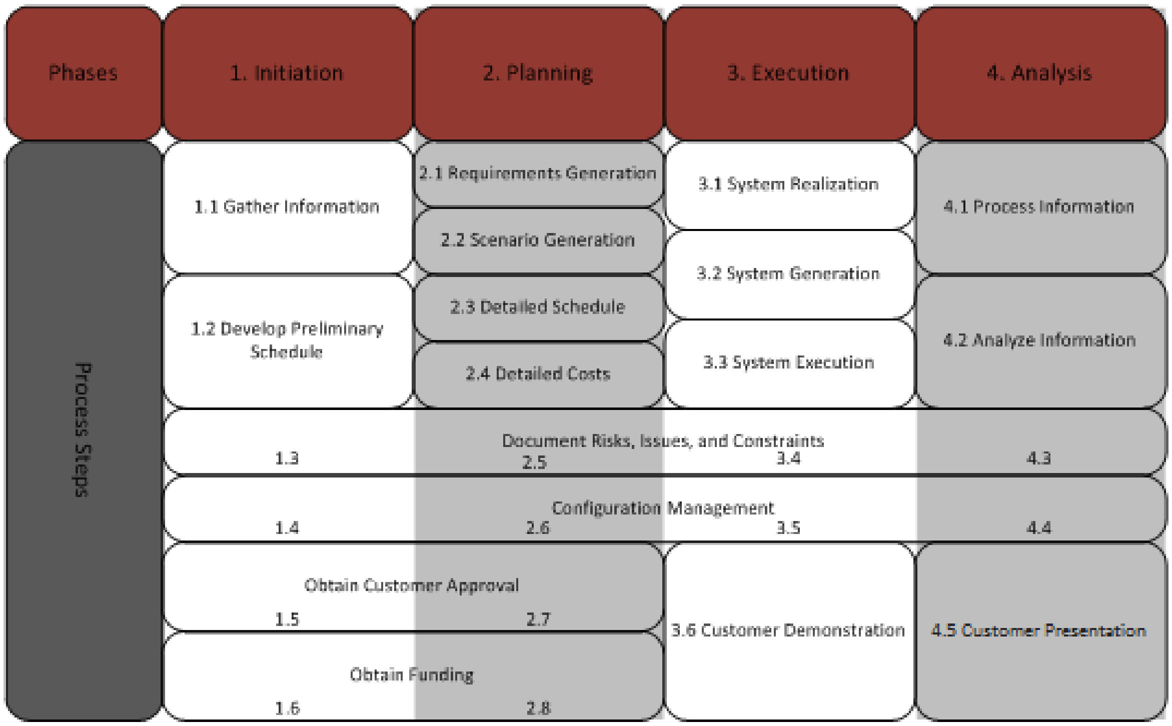

Figure 3. Current Proposed Architectural Process

While the process exists using pre-established phases, steps, and personnel roles, it should in no way be taken to mean that no other phases, steps, or personnel roles can be added, deleted, or modified. Having the ability to adjust the process as necessary is a critical condition to the success of employing the process itself.

Finally, it is anticipated that capturing time spent in each category will show relationships such as the less time spent planning, the more time and expense spent in the latter categories. Likewise, developing such trends will also assist in estimating cost and schedule for future projects.

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II. CURRENT ARDEC PROCESSES, PROPOSED PROCESS STRUCTURE AND DESCRIPTION

A. CURRENT ARDEC PROCESSES

There is no institutionalized methodology used to conduct operational simulation and analyses within the OS&A branch. As a result, new projects are initiated without consideration to past lessons learned. This is highly undesirable since aspects of previous analyses may apply to current studies resulting in a significant savings of cost and time. By implementing a configuration management scheme to maintain record of previous work performed, the OS&A branch would build up additional background data to further support analytical results and assist the Project Lead in obtaining results more quickly.

Furthermore, issues such as striving for continuous improvement by adapting to best business practices (BBPs), heuristics, and current tactics, techniques, and procedures (TTPs) have not been adopted consistently nor has the emphasis of capturing the appropriate problem space early in the process.

Finally, projects are forced into cost, schedule, and performance overruns from the start because the government business model calls for time and schedule estimates before the scope of the problem statement and project requirements are methodically derived. Issues such as these have caused the branch to lose credibility in the eyes of the customer.

An example of one project which suffered due to lack of a standardized process was the Homeland Defense (HLD) Project (Przywozny 2010). This project entailed simulating an attack at a public transportation terminal located within the United States. As a result of not adopting a systems engineering process, the ARDEC Project Officer (APO) aka Project Lead was given a massive responsibility to not only execute the study without the discipline of a systems approach, but to also provide the direction, control, and oversight to all aspects of the study.

This particular project encountered issues at inception when the customer dictated the modeling and simulation application solution set to be used. Such an imposition proved detrimental throughout the execution of the analysis. The problem statement which was later concluded to be the following:

"*Analyze the force effectiveness of ARDEC products within a given scenario*," became:

"*Assess the utility of the imposed solution set for analyzing the force effectiveness of ARDEC products within a given scenario.*"

Upon a peer review of the project after its completion, one issue was that no process which resulted in the generation of a methodically researched problem statement had been executed. Consequentially, no formal agreement had been made between the customer and project lead indicating a common understanding of the project and problem statement at hand.

Furthermore, as a result of imposing a solution prior to fully understanding the problem itself, a fundamental axiom to the very essence of implementing the systems approach (Avoid premature adoption of 'the solution') was violated:

Succinctly stated, "The design team should be careful to avoid early adoption of a candidate system from a previous mission in order to avoid being locked into a system that only marginally meets or does not meet your objectives/requirements." (National Council of Space Grant Directors 2012)

Finally, the timeline and cost estimates were severely underestimated. This occurred because clarifications of the customer objective and upfront statements of risks, issues, and constraints were not identified. Had the incorporation of a systems approach such as the process proposed been in place and exercised, it is likely that the determination that the scope of the scenario coupled with the constraints dictated by the customer was beyond the Project Lead's grasp given the amount resources available. Additionally, since there had been no configuration management practice in place, there was no previous reference with which to draw upon in order to determine if a similar project such as this had been exercised before.

B. PROPOSED PROCESS STRUCTURE

1. Overview

The proposed process has been abstracted into four key phases. Within each phase, steps and sub-steps are outlined. The overall architecture provides general guidance and allows the Project Lead to adapt as applicable to their specific project. The phases: Initiation, Planning, Execution, and Analysis represent major categories of project progression and align with the DoD 5000 Defense Acquisition System Life Cycle Model as illustrated in Figure 4 (Defense Acquisition University 2011).

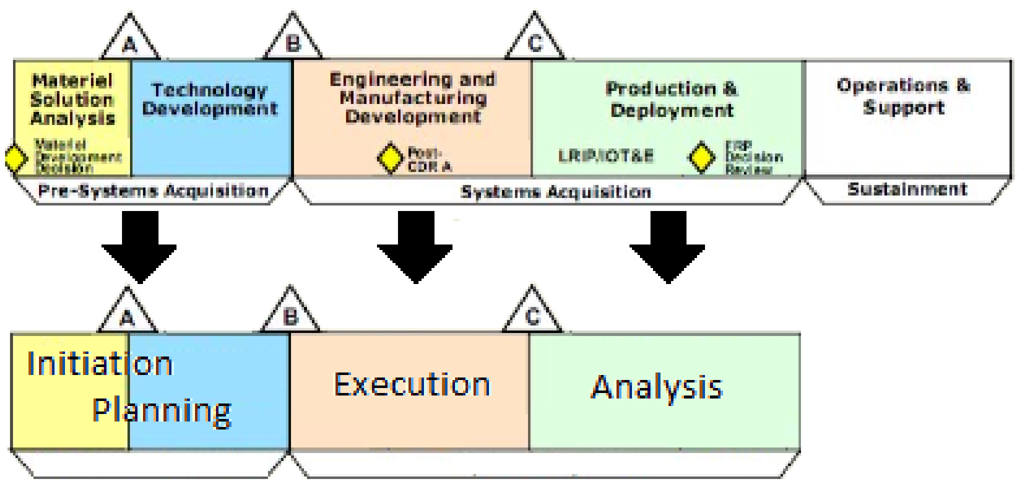

Figure 4. Process Alignment with DoD Defense Acquisition System Life Cycle Framework (From: Defense Acquisition University 2011)

The encapsulated steps are designed to support the current phase, iterative by nature, and sequential. Typically, resultant data from one step becomes input for the next. A branch hierarchy and definition of personnel roles for each step are also defined in order to assist the Project Lead in developing a project schedule and budget reliably and apply the technique of resource balancing. Potential implications resulting from changes to DoD life cycle policies serve to emphasize the fluidity of the proposed process. While

the process is not required to map to the DoD 5000 life cycle, the intent of the comparison is to provide the Project Lead an element of confidence and familiarity when adopting this process.

2. Branch Hierarchy and Personnel Roles

Figure 5 illustrates the Operational Simulation & Analysis (OS&A) branch structure and key player hierarchy. This hierarchy was created through the OS&A branch's collective vision of what the structure of a balanced analytical team should look like and was further refined when put into practice This hierarchy serves as the primary resource for the personnel roles defined in the following table.

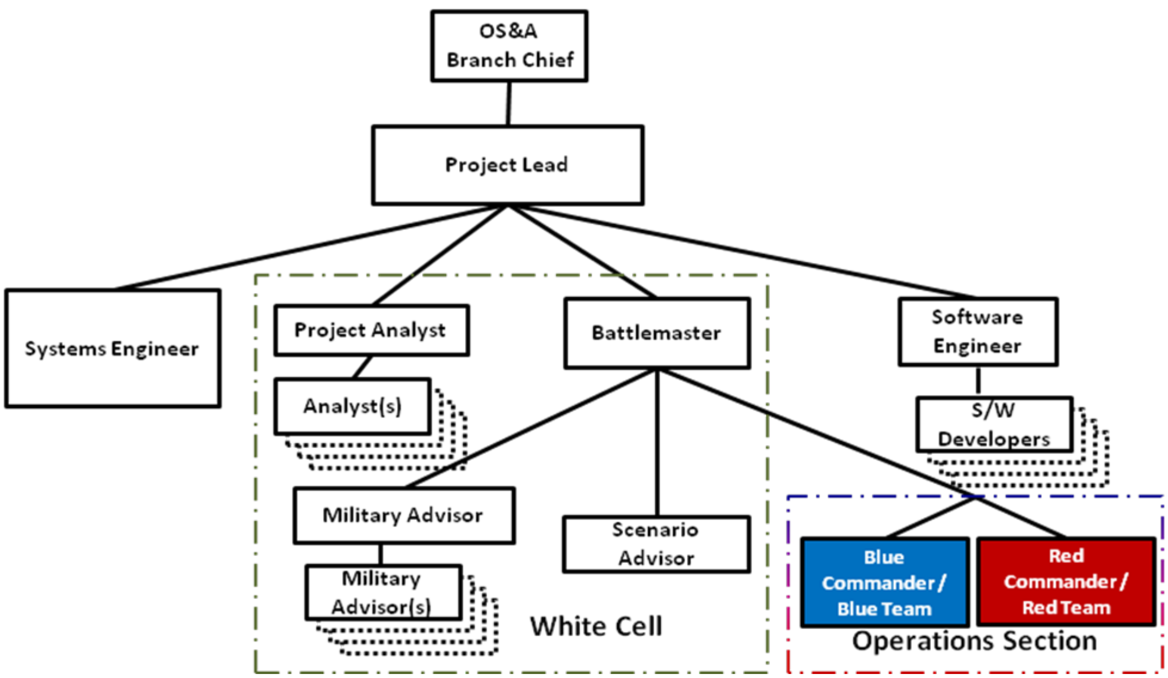

Figure 5. Typical Operational Simulation & Analysis Branch Personnel / Role Structure (From: Luzzi 2010)

Table 1 presents (in alphabetical order) descriptions of the roles introduced in Figure 5. Additionally, the roles of customer, network administrator, and stakeholder have been added. While these roles are not illustrated in the figure above, this discrepancy serves a benefit by showing that these processes and structures are indeed living and will likely be incorporated into future versions of the OS&A branch hierarchy.

Role	Description
Battlemaster	Individual who maintains control of scenario execution
Blue Player / Commander / Team	Any entity; human or machine; which acts on the 'friendly' side of the scenario
Customer	Any individual or organization who places a vested interest in the project
Military Advisor (Lead)	Individual who serves as the scenario subject matter expert ensuring that the scenario defined for the project is relevant
Network Administrator	Individual who maintains and implements the necessary communications and routing as required by and best suited for the project's needs
Project Analyst / Lead Analyst	Individual responsible for defining what data needs to be collected in order to produce the requested analyses, as well as all mathematical and statistical calculations necessary to derive results. In most cases, the project analyst will have specific subject matter expertise in ORSA
Project Lead	Individual who serves as the customer's focal point and manages project cost and schedule
Red Player / Commander / Team	Any entity, human or machine, which acts on the 'enemy' side of the scenario
Software Engineer / Lead / Developers	Individual who develops, modifies, acquires or configures software for the project
Stakeholder	Anyone who has exposure to, affects, or is affected by the analyses conducted.
Supervisor / OS&A branch Chief	Individual who facilitates the Project Lead and commits to assuring provision of assets funding and time
Systems Engineer	Individual responsible for ensuring that all aspects of the project's System's Engineering functions are being executed

Table 1. Process Key Players and Descriptions

C. PROCESS DESCRIPTION

The remainder of this thesis shall illustrate the proposed process using the following structure:

- A flowchart figure depicting current phase, step, or sub-step.
- A table indicating key players, inputs, and outputs for the current phase, step, or sub-step
- A discussion of current phase, step, or sub-step

1. Project Initiation Phase

The *Project Initiation* phase (Figure 6) consists of six steps which are intended to provide the Project Lead with a precursory view of the problem space. Moreover, it is important to make the distinction that this phase is targeted toward establishing the project scope than to the application of the systems approach itself. The systems approach is implemented in the planning phase as will be discussed in Section 2. The only thing assumed about the project at this time is that there has been a stated analytical need.

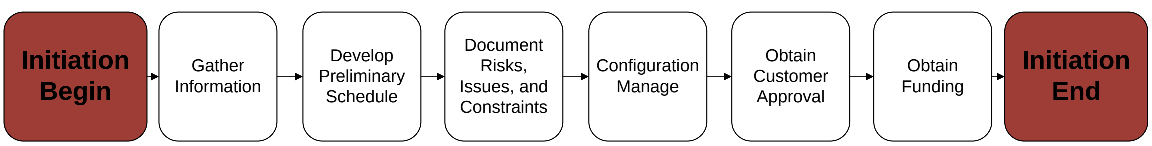

Figure 6. Initiation Phase of the Proposed Process

Key Players	Inputs	Outputs
Systems Engineer Project Lead Project Analyst Developers	Need for Analysis to be conducted	Initial (Retainer) Funding

Table 2. Key Players, Inputs, and Outputs for the Project Initiation Phase

a. Gather Information

The purpose of the *Gather Information* step is to elicit responses from the customer in order to gain initial insight to the problem at hand. Activities include customer and stakeholder identification and interview. The Project Lead and Systems Engineer gather information to identify the project scope, customer's anticipated timeline for project initiation and completion, the general level of financial investment on the customer's behalf, and initial concerns that could negatively affect the outcome of the project.

Figure 7. Gather Information Step within the Initiation Phase

Key Players	Inputs	Outputs
Systems Engineer Project Lead	Need for Analysis to be conducted	General Information

Table 3. Key Players, Inputs, and Outputs for the Gather Information Step

In doing so, the Project Lead and Systems Engineer develop an initial insight into the analysis requested and the initial constraints within which the project is bound. Failure to adequately conduct this portion of the information gathering process can lead to misguided customer and stakeholder identification, erroneous impression of common and disjoint visions, and an overall poor initial understanding of the problem space which may result in cost, schedule, and performance overruns.

(1) Identify Customers. A customer is a "user, operator, and integrator of operational products at any position within a system structure" (Defense Acquisition University 2011). In projects that have multiple customers, it is the responsibility of the Project Lead and Systems Engineer to ensure the final product realizes the collective vision of these customers.

Key Players	Inputs	Outputs
Systems Engineer Project Lead	People interested in the project	Customer List

Table 4. Key Players, Inputs, and Outputs for the Identify Customers Step

(2) Identify Stakeholders. A stakeholder is an "Individual or organization having a right, share, claim, or interest in a system or in its possession of characteristics that meet their needs and expectations" (Stevens Institute of Technology 2011). Furthermore, "Stakeholders include, but are not limited to end users, end user organizations, supporters, developers, producers, trainers, maintainers, disposers, acquirers, customers, operators, supplier organizations and regulatory bodies" (Stevens Institute of Technology 2011).

Key Players	Inputs	Outputs
Systems Engineer Project Lead	People interested in the project	Stakeholder List

Table 5. Key Players, Inputs, and Outputs for the Identify Stakeholders Step

(3) Conduct Interviews. Interviewing customers and stakeholders is the key to obtaining a grasp as to the scope of the problem space. It bears reiteration that the purpose of conducting interviews during this phase relates more to identifying who the players are, what their understanding of the perceived need is, and gain a very high level impression of scope of the project. The interviewing process begins with gathering notes on each customer's perceived needs, thus deriving customer expectations prior to any systems approach implementation.

Key Players	Inputs	Outputs
Systems Engineer Project Lead Project Analyst	Customer and Stakeholder identification	Top Level Requirements and Expectations, System ConOps

Table 6. Key Players, Inputs, and Outputs for the Conduct Interviews Step

The Systems Engineer, in conjunction with the Project Lead and Project Analyst take the time to interview stakeholder and customers with the goal of ascertaining the following information:

- Do the customers know what they want?
- Do the customers have the same goals?
- What is the level of effort of this project?
- Who needs to be involved?
- What is the timeline from project start to completion?
- What is the financial investment of the funding organization?

It is important to note that the interviews conducted provide a general picture of what is desired but do not constitute the "Requirements Elicitation" process which occurs in the following phase. The purpose of this step is to understand a component unique to the field of operational analyses–scenario aggregation.

The size and aggregation of a scenario is directly proportional to the level of effort involved. Executing analyses which assess the performance of a single item requires considerably less effort than executing analyses which assess the effect an item has on the overall outcome of a large scale engagement. For example, the level of effort involved in analyzing the probability of acquisition of an acoustic sensor through modeling and simulation is less than analyzing how that same acoustic sensor affects the entire outcome of an engagement.

As such, this step establishes top level perceptions and expectations of the customers and stakeholders and forms a precursory concept of operations. The concept of operations, or ConOps, is defined to "describe how the system will be operated during the life-cycle phases to meet stakeholder expectations. It describes the system characteristics from an operational perspective and helps facilitate an understanding of the system goals" (NASA 2007).

b. Develop Preliminary Schedule

Projections that address potential resources needed should be made and updated as necessary. After initially identifying resources by job description or by naming a specific individual, the Systems Engineer and Project Lead can establish a baseline schedule. Most commonly used is the work breakdown structure (WBS). The WBS is, “a product-oriented family tree composed of hardware, software, services, data, and facilities … results from Systems Engineering efforts” (Defense Acquisition University 2011). This schedule is understood to be preliminary and is likely to be updated frequently.

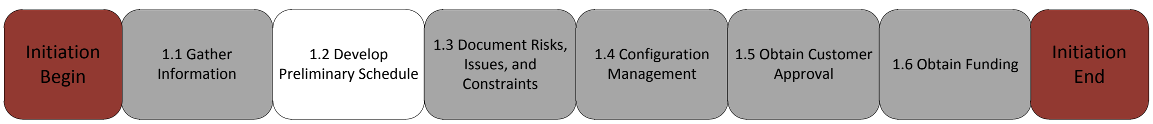

Figure 8. Develop Preliminary Schedule Step of the Initiation Phase

Key Players	Inputs	Outputs
Systems Engineer Project Lead	Interview Notes	Preliminary Schedule

Table 7. Key Players, Inputs, and Outputs for the Develop Preliminary Schedule Step

c. Document Risks, Issues, and Constraints

Risk is defined as the “measure of the inability to achieve overall program objectives within defined cost, schedule, and technical constraints and has two components: (1) the probability of failing to achieve a particular outcome and (2) the consequences / impacts of failing to achieve that outcome.” (NASA 2007).

The goal of this step is to clearly identify potential project pitfalls and to ultimately be proactive in addressing them as opposed to reacting to them once they occur. Furthermore, continual consideration of risks, issues, and constraints give the

customer a realistic view and help ground their expectations. Documenting risks, issues, and constraints provide an element of protection to the Project Lead such that any potential pitfall that may be encountered is documented, discussed, and the remedies and mitigations set forth are agreeable to all parties involved.

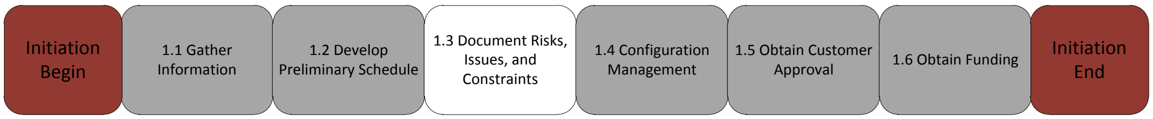

Figure 9. Document Risks, Issues, and Constraints Step in the Initiation Phase

Key Players	Inputs	Outputs
Systems Engineer Project Lead	Interview Notes, Preliminary Schedule	Open statements of concern for stakeholders to consider

Table 8. Key Players, Inputs, and Outputs for the Document Risks, Issues, and Constraints Step

It is critical that the Risks, Issues, and Constraints are monitored continually, as the project progresses, the status of these items will most assuredly change. Within the process, just as in the Defense Acquisition University's discipline of System's Acquisition, risk identification will be categorized as low, moderate, and high based the likelihood of the event occurring and severity of occurrence.

The following figure depicts a typical risk matrix:

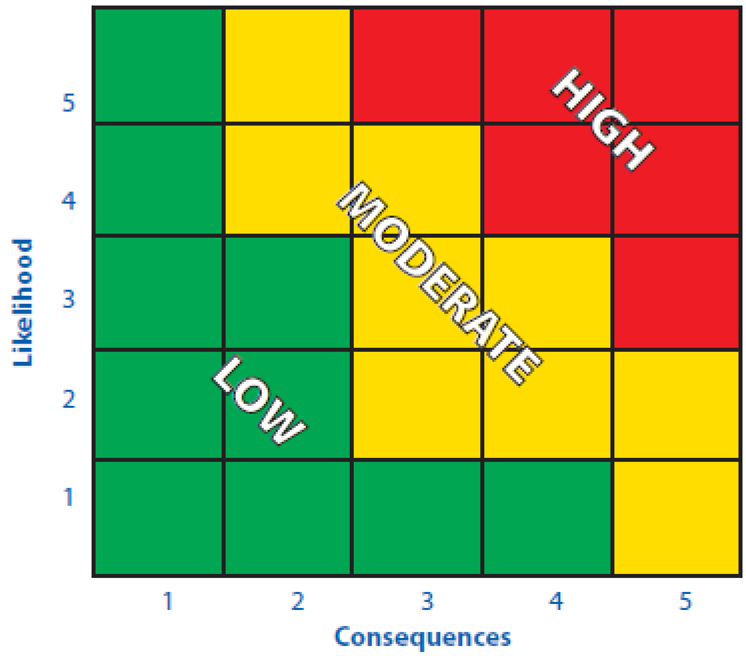

Figure 10. Matrix Used to Assess Level of Risk Based on the Likelihood of Occurrence Cross Referenced with the Severity of the Consequence (From: NASA 2007)

For all identified risks, a mitigation approach is identified. Additionally, risk concerns require multiple iterations throughout the life cycle of the project. Since the process does not change, future occurrences of the “Document Risks, Issues, and Constraints” step are referred back to this section.

Table 9 summarizes the Continuous Risk Management (CRM) process employed and referenced in the NASA Systems Engineering Handbook:

Step	Explanation
Identify	Statement of risk, likelihood and scenario with which it may occur
Analyze	Estimate likelihood and severity of risk
Plan	Establish method to monitor established risk
Track	Maintain current status of each risk, including new observations, and resolutions
Control	Execution of plan
Communicate & Document	Living record of risks identified

Table 9. NASA Continuous Risk Management (CRM) Process (From: NASA 2007)

Issues are immediate problems which must be solved (Best-Practice.com 2012). The failure to address risks within their appropriate scope will result in issues. One example of an issue encountered during the HLD Case Study (described in Chapter II, Section B) was the determination of the desired scenario size. In order to model the scenario realistically, developers needed to create thousands of entities using a 3-D modeling application such as Presagis' Creator©, DI-Guy©, or PTC's Pro-Engineer©. Entities requiring simulation ranged from human actors, to high resolution vehicles, buildings, and explosive ordnance. Development of such entities requires a significant time investment based on fidelity (also further emphasizing the importance of configuration management; reduce, reuse, and recycle). During the interview process, the scenario size quickly became recognized as a risk. However, this risk was not identified the costumer and as the project progressed, it quickly resulted in an issue. Failure to reduce the scope of the scenario in order to create a manageable scenario size resulted in an issue during the scenario generation process. In turn, the project suffered in terms of schedule since the scenario had to be reduced at such a late point in the project.

Finally, constraints, as opposed to issues, are limitations imposed upon the project by some means; including but not limited to requirements, technological limitations, timelines and personnel.

d. Configuration Management

The NASA Systems Engineering handbook defines Configuration Management as,

> a management discipline applied over the product's life cycle to provide visibility into and to control changes to performance and functional and physical characteristics. Configuration Management ensures that the configuration of a product is known and reflected in product information, that any product change is beneficial and is effected without adverse consequences, and that changes are managed. (NASA 2007)

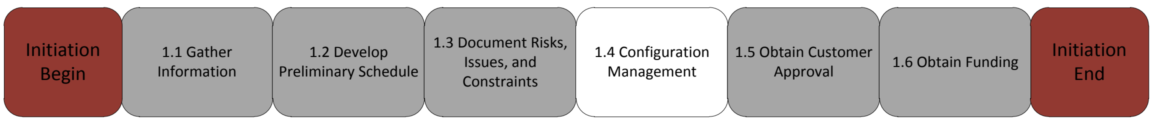

Figure 11. Configuration Management Step of the Initiation Phase

Key Players	Inputs	Outputs
Project Lead Developers	Interview Notes, Preliminary Schedule, Risks, Issues and Constraints	Controlled method to preserve data

Table 10. Key Players, Inputs, and Outputs for the Configuration Management Step

Furthermore, use of configuration management "reduces technical risks by ensuring correct product configurations, distinguishes among product versions, ensures consistency between the product and information about the product, and avoids the embarrassment of stakeholder dissatisfaction and complaint" (NASA 2007).

Use of a configuration management system is of the utmost importance. By employing a configuration management very early in the process, the Systems Engineer and project employees can document where diversions are made, and people working on future projects can refer back to this asset library to see what can be reused, thus creating a major benefit in terms of time, cost, and schedule reduction.

The configuration management library is the primary hub in which all recorded data is maintained for the life of the project and beyond. All artifacts from the earliest to the latest phase of the cycle should be contained within this library as it is elemental for providing justifications and reiterations of actions and reactions taken. Use of a configuration management policy protects the Project Lead and workers such that it is used to provide a running record for activities. Also of great importance is the ability to look back over specific time periods to determine what activities were occurring at that time and why. Requirements which have changed are captured through this mechanism and provide a record for use in future projects which may reuse parts of the data or scenario recorded.

Table 11 provides an excellent structure for the configuration management of requirements. This table is located in chapter 4 of the NASA Systems Engineering handbook.

Item	Function
Requirement ID	Unique numbering system for sorting and tracking
Rationale	Additional information which clarifies the requirement intent at time of writing
Traced From	Capture bi-directional traceability from parent to child requirements
Owner	Party responsible for achieving, managing, and/or approving changes to requirement
Verification Method	Captures method of verification (test, inspection, analysis, demonstration)
Verification Lead	Person responsible for verifying the requirement
Verification Level	Specifies level in which requirement will be verified (system, subsystem, component, etc.)

Table 11. NASA Requirements Meta-Data (From: NASA 2007)

Since the process does not change future occurrences of the Configuration Management step are referred back to this section.

e. Obtain Customer Approval

Customer approval at this juncture indicates that the Project Lead and Systems Engineer have interpreted the problem correctly and that there has been sufficient communication with the customer to derive revised and updated goals and necessary plans. The approval obtained indicates that the customer agrees to the problem definition and proposed manner of project execution.

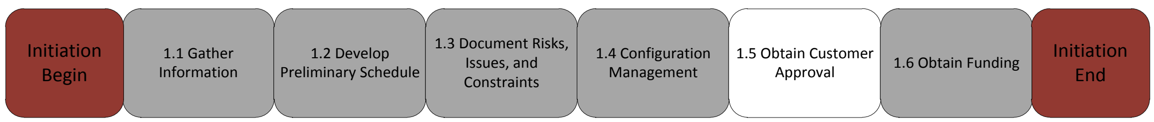

Figure 12. Obtain Customer Approval Step of the Initiation Phase

Key Players	Inputs	Outputs
Project Lead	Configuration Managed Data	Customer Reaction

Table 12. Key Players, Inputs, and Outputs for the Obtain Customer Approval Step

f. Obtain Funding

This step requires that funding be established as a standard amount in order for the Project Lead and designated team members to receive compensation for their efforts. In support of implementing this 'retainer' funding concept, consider the government acquisition process where one of the preconditions to achieving Milestone B is having secured funding for the remainder of the project. Such a stipulation implies that other activities previous to Milestone B which were accomplished through a different set of funds.

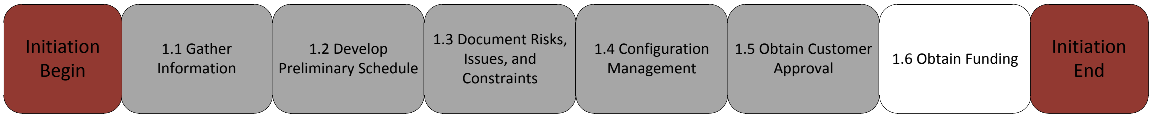

Figure 13. Obtain Funding Step of the Initiation Phase

Key Players	Inputs	Outputs
Project Lead	Customer Reaction	Customer Funding

Table 13. Key Players, Inputs, and Outputs for the Obtain Funding Step

The process proposed asks for the same separation of funding however; it is a highly debatable notion which does not currently exist within the government's business model for performing analyses. Nevertheless, it is imperative to point out that this has historically been a critical failure area. An unacceptable amount of risk is often assumed when costs and timelines are determined prior to proper breakdown and analysis of system requirements.

> Early decisions in the Systems Engineering process tend to have the greatest effect on the resultant system life-cycle cost" (NASA 2007). "Typically, by the time the preferred system architecture is selected, between 50 and 70 percent of the system's life-cycle cost has been locked in" (NASA 2007). "By the time a preliminary system design is selected, this figure may be as high as 90 percent. This presents a major dilemma to the Systems Engineer, who must lead this selection process. Just at the time when decisions are most critical, the state of information about the alternatives is least certain. (NASA 2007).

2. Planning Phase

Historically, the key in defining success for most projects lie in a significant investment of personnel in the planning phase. The action of planning, which is discussed throughout this document is generally underestimated. When this occurs, executing projects suffer in terms or cost, schedule, performance, or some combination of all three. In addition, lack of thorough planning, either from lack of time or lack of resources, ultimately contributes to the reputation of the branch. Maintaining a reputation of high standards is critical to mission success and sustenance of the division. In general, one can estimate that the steps detailed in the process's Planning Phase will consume up to half of the project's lifetime, though probably not so much of the budget since there are fewer resources needed in this phase than in others. This phase consists of all activities necessary to determine the customer's requirements and devise a mechanism which exercises said requirements.

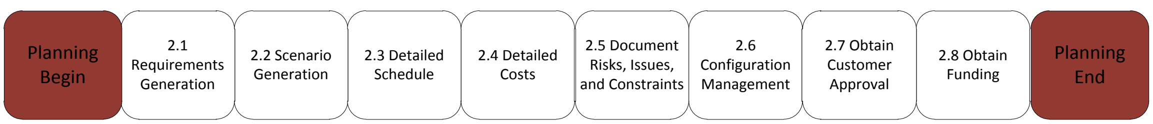

Figure 14. Planning Phase

Key Players	Inputs	Outputs
Systems Engineer Project Lead Project Analyst Military Advisor Software Engineer & Developers	Stakeholder and Customer Identification	Problem Statement Requirements Metrics Scenario Data Collection Plan

Table 14. Key Players, Inputs, and Outputs for the Planning Phase

a. Requirements Generation

The requirements generation step is arguably the most important predictor as to the outcome of the project. Well defined requirements lead to well defined objectives for analyses while poorly defined requirements lead to confusion. Technical requirements are, "the approved set of requirements that represents a complete description of the problem to be solved and requirements that have been validated and approved by the customer and stakeholders" (NASA 2007).

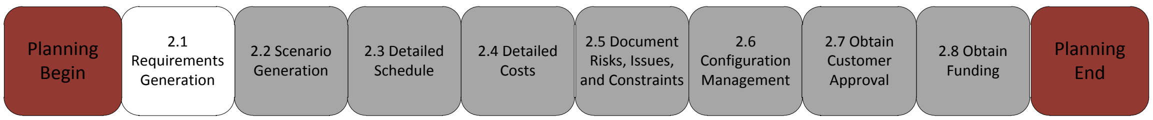

Figure 15. Requirements Generation Step of the Planning Phase

Key Players	Inputs	Outputs
Systems Engineer Project Lead	Identified Customers and Stakeholders	High Level Requirements

Table 15. Key Players, Inputs, and Outputs for the Requirements Generation Step

(1) Establish the Problem Statement. After initial and follow up interviews, the Systems Engineer should have a fairly clear picture of the customer hierarchy and dynamic. The problem statement, which is a "brief, concise statement of fact that clearly describes an undesirable state or condition without identifying the source or actions required to solve the problem" (Wasson 2005), should be as concise as possible without being contrived. There is a delicate balance between making the problem statement too short, such that elements are left for interpretation, and too long such that the scope of the project is far

Key Players	Inputs	Outputs
Systems Engineer Project Lead	High Level Requirements	Problem Statement

Table 16. Key Players, Inputs, and Outputs for the Establish the Problem Statement Sub-Step

After initial and follow up interviews, the Systems Engineer should have a fairly clear picture of the customer hierarchy and dynamic. The problem statement, which is a “brief, concise statement of fact that clearly describes an undesirable state or condition without identifying the source or actions required to solve the problem” (Wasson 2005), should be as concise as possible without being contrived. There is a delicate balance between making the problem statement too short, such that elements are left for interpretation, and too long such that the scope of the project is far too daunting an undertaking. In general, the problem statement should span from a simple sentence to a few sentences forming no more than a brief paragraph.

When deriving the problem statement, it is best to keep the following practices in mind:

- Do not identify the cause of the problem; simply state what the problem is
- Do provide the environment which precipitates the problem
- Do not establish any explicit or implicit solutions (Wasson 2005)

(2) Decompose the Problem Statement. Decomposition of the problem statement or partitioning the problem space is the first step to grasping the complete context of the issue at hand. Decomposition, or partitioning, provides the ability to, “isolate key properties and characteristics of the problem as abstractions that enable us to ultimately develop solutions” (Wasson 2005). The problem statement decomposition has the following characteristics.

- Components are distinct
- Functions are not redundant
- Interfaces between components are clear

Key Players	Inputs	Outputs
Systems Engineer	Problem Statement	Problem Statement Decomposition

Table 17. Key Players, Inputs, and Outputs for the Decompose the Problem Statement Sub-Step

It is from the problem statement decomposition that we can impose some order, or outline and clearly define the requirements.

(3) Identify Requirements. Requirements need to be stated in unambiguous terms. Requirements derivation is, “The act of decomposing an abstract parent requirement into lower level objective, performance-based sibling actions. Collective accomplishment of the set of derived “sibling” actions constitutes satisfactory accomplishment of the “parent” requirement” (Wasson 2005).

Key Players	Inputs	Outputs
Systems Engineer Project Lead	Interview Notes High Level Requirements Problem Statement Problem Statement Decomposition	Detailed Requirements

Table 18. Key Players, Inputs, and Outputs for the Identify Requirements Sub-Step

Well stated requirements are explicit and demonstrate minimal risk for misinterpretation. Additionally, requirement relevancy is assured through a traceability process which ensures requirements are complete. Furthermore, requirements each have a subjective value and priority to the user, impose constraints on design solution options, potentially increase risk, and have a cost associated with them for implementation and maintenance.

Requirements should be:

- unique within the system,
- singular in purpose,
- consistent with other requirements
- non-conflicting
- explicitly realistic, achievable, consistent, testable, measurable, and verifiable
- assigned to an owner who is accountable for its implementation and maintenance (NASA 2007, Wasson 2005)

Finally, a requirement is considered finalized if and only if it is traceable to the problem statement, has an established verification method (generally some level or type of testing), and is agreed upon by the customers/stakeholders. Well defined requirements establish the basis for agreement between the stakeholders and the Project Lead on what the project is to accomplish. They provide a basis for reliably estimating costs and schedules, and provide a verification and validation baseline (NASA 2007).

(4) Create Evaluation Metrics. Once requirements have been established in quantifiable terms, the Systems Engineer must attempt to apply values and thresholds in order to establish whether or not the requirement has indeed been met. Additionally, the Systems Engineer should have a good idea of the relative importance of the requirements, as some are more critical than others. The weighting of these requirements will ultimately factor into any trade off comparison.

Key Players	Inputs	Outputs
Systems Engineer Project Lead System Analyst	Detailed Requirements	Evaluation Metrics

Table 19. Key Players, Inputs, and Outputs for the Create Evaluation Metrics Sub-Step

Measures of evaluation, or Technical Performance Measures are, "An established set of measures based on the expectations and requirements that will be tracked and assessed to determine overall system or product effectiveness and customer satisfaction" (Wasson 2005). Terms used for these evaluation metrics are based on the type of analysis being performed. The level of aggregation of the scenario under analysis typically determines which measures will be used. In the OS&A branch's case, the most commonly used measure is the Measure of Effectiveness (MOEs). Figure 16, from the INCOSE Technical Measurement Guide, demonstrates the hierarchy of technical measures.

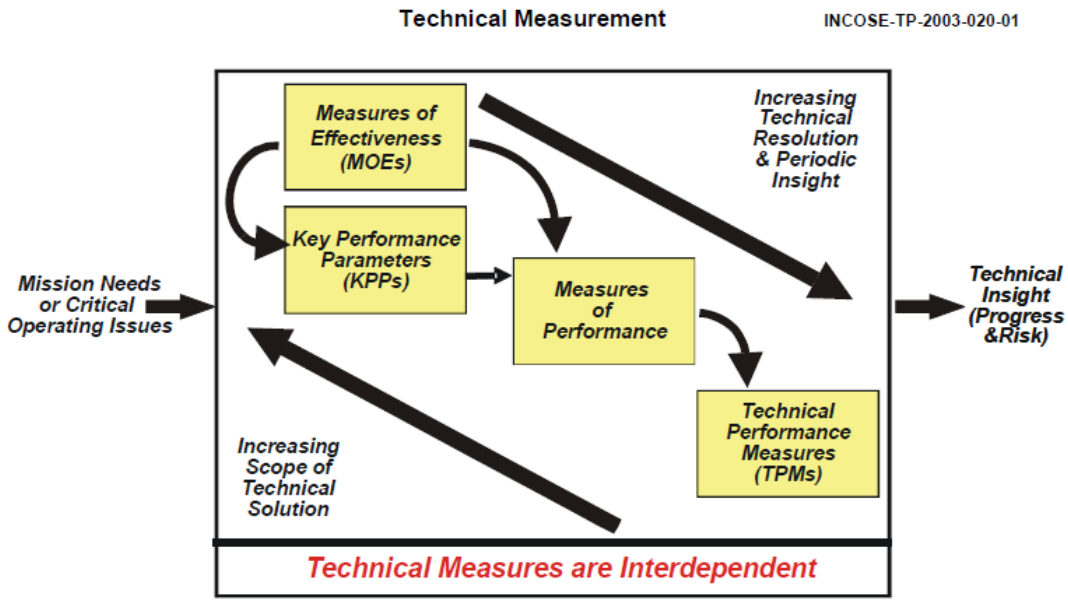

Figure 16. Relationship of the Technical Measures (From: Roedler 2005)

(5) Create Functional Decomposition. The functional decomposition is the logical compartmentalization of requirements into groups. The ability to separate families of requirements into chunks allows for a modular approach. This is an important step to perform as it also helps to define the resources needed to accomplish any task. The functional decomposition is intended to "translate top-level requirements into functions that must be performed to accomplish the requirements. Decompose and allocate the functions to lower levels of the product breakdown structure. Identify and describe functional and subsystem interfaces" (NASA 2007). Finally, the resultant set of documents composes the functional baseline for the system.

Key Players	Inputs	Outputs
Systems Engineer	Detailed Requirements	Functional Decomposition Project Scenario Specification (System Specification)

Table 20. Key Players, Inputs, and Outputs for the Create Functional Decomposition Sub-Step

For our purposes, the output of this process is referred to as the "Project Scenario Specification." This specification serves as the baseline of activities which the scenario must exercise. The Project Scenario Specification should be thorough enough such that there is sufficient guidance and constraints for the project analyst and military advisor to develop a comprehensive scenario which will exercise all aspects of the requirements set forth.

b. *Scenario Generation*

The Scenario Generation Step defines a storyboard which exercises each requirement in a manner consistent with its evaluation method.

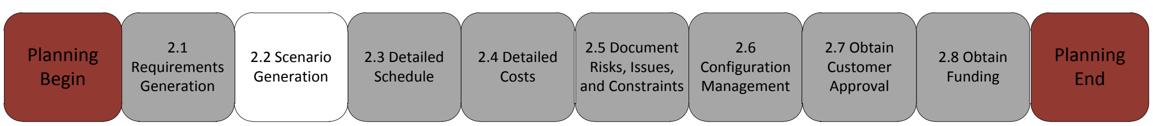

Figure 17. Scenario Generation step of the Planning Phase

Key Players	Inputs	Outputs
Systems Engineer System Analyst Military Advisor	Detailed Requirements Functional Decomposition	Scenario Data Collection Plan

Table 21. Key Players, Inputs, and Outputs for the Scenario Generation Step

(1) Define Scenario. Given the requirements, functional decomposition, system design specification, documented risks and constraints and configuration management scheme; the Project Lead, Project Analyst, and Military Advisor define a real world scenario that will accurately and realistically exercise all requirements set forth. Over time, it is likely that there will have already been scenarios established that will fit the existing projects needs with a few tweaks. Reviewing past projects should always be the first step to scenario definition and as a result, two outcomes will occur. One possibility is that the Systems Engineer will find an appropriate scenario given some adjustments. In this case, the scenario should be reviewed with a Military Advisor to confirm the scenario's relevance to the real world. The second possibility is that there is no scenario available to exercise the requirements and a new scenario must be created. One suggested method for scenario development is by way of a logical/functional architecture development methodology or logical decomposition.

Key Players	Inputs	Outputs
Project Lead Project Analyst Military Advisor	Requirements Functional Decomposition Metrics	Storyboard Scenario Interactions Matrix Storyboard Logical/Functional Architecture

Table 22. Key Players, Inputs, and Outputs for the Define Scenario Sub-Step

A logical decomposition defines the 'what' which must be achieved by the system at each level to enable a successful project (NASA 2007). The functional decomposition described in the previous step above is an element of logical decomposition. This process enables the Project Lead and Systems Engineer to thoroughly understand the requirement at hand and to break it down into logical components. Inputs to decomposition include the technical requirements and measures.

This process of functional and logical decomposition enables elements of the overall system to be developed independently. The advantage of doing so is evident in terms of risk and time reductions. Tools used and design elements produced from this

activity include work-breakdown structure (WBS), Functional Flow Block Diagrams (FFBD), and N2 Diagrams. While the original intent for these standards, processes, and tools are for the development and manufacturing of physical systems, the best practices apply and are also in alignment with the development of Modeling and Simulation Analytical systems.

Functional Flow block diagrams depict a sequence of activities or functions which are derived from the requirements and form the design (NASA 2007). The FFBD, as seen in Figure 18, illustrates sequential as well as parallel activities. In application to the proposed process, an FFBD would be applied to the scenario generation section. It is important to note that FFBDs are considered high level because they define what is to occur, but not how it occurs.

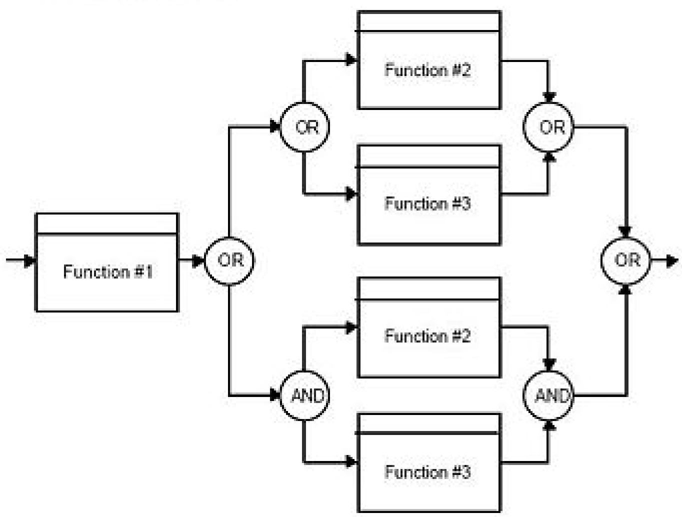

Figure 18. Sample Functional Flow Block Diagram (FFBD)

N2 (or N-squared) diagrams, as shown in Figure 19, define functional interfaces between components (NASA 2007). The combination of the WBS, FFBDs, and N2 diagrams provide to the customer a hierarchical functional breakdown of the parent requirements (NASA 2007).

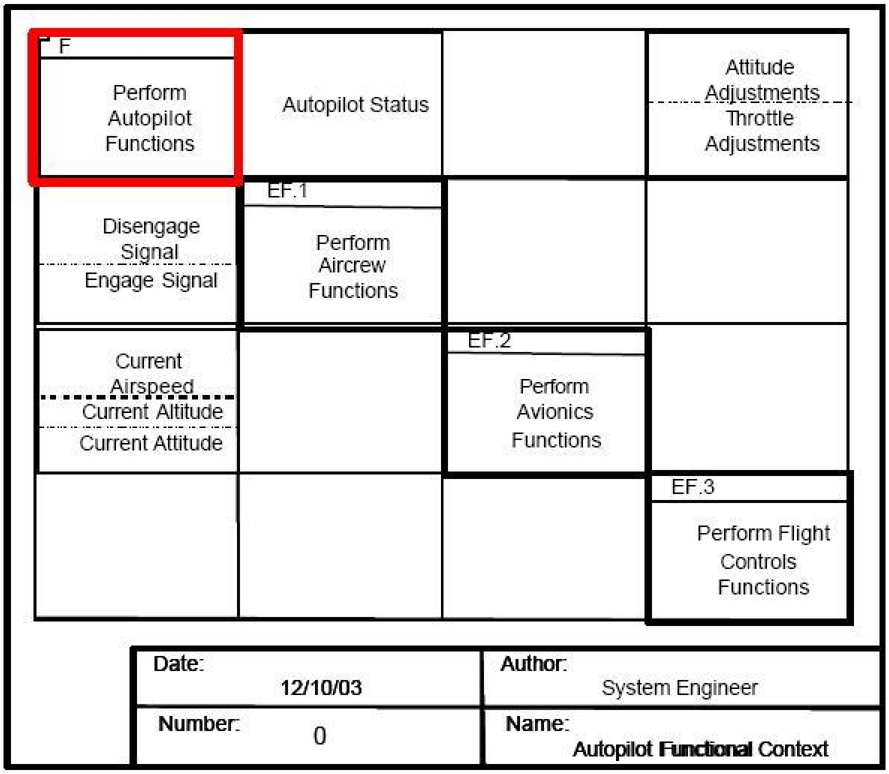

Figure 19. Sample N2 (N-squared) Diagram

As per the Wasson text, the logical decomposition process consists of the following steps:

1: Identify logical objects or entities

2: Identify each entity's capabilities

3: Create a logical interactions matrix

4: Create the logical/functional architecture (Wasson 2005)

Conduct Traceability between Requirements and Scenario. As the scenario is generated, traceability is verified via a document or spreadsheet indicating how scenario elements touch upon the requirements. The scenario must exercise all of the requirements. If this is not the case, the scenario must be reworked or the requirements revisited. At this phase in the life cycle, scenario modification will likely be the less expensive of the two options.

Key Players	Inputs	Outputs
Systems Engineer	Detailed Requirements Scenario	Traceability Matrix

Table 23. Key Players, Inputs, and Outputs for the Conduct Traceability Sub-Step

(2) Identify and Resolve Gaps. The act of Gap Identification and Resolution closes out any outstanding items. If an amenable resolution is unattainable, the Project Lead and Systems Engineer must discuss this with the customer and stakeholders then backtrack through the previous steps to come up with a set of attainable requirements, scenario, or both. In comparison with the Systems Engineering handbook for design and development of systems, this step is nearly synonymous with the Analysis of Alternatives step.

Key Players	Inputs	Outputs
Project Lead System Analyst Developers	Gaps Identified through traceability activity	Solutions that will, meet needs as stated, modify requirements, or modify the scenario.

Table 24. Key Players, Inputs, and Outputs for the Identify and Resolve Gaps Sub-Step

(3) Define Data Collection Plan. The Data Collection plan defines all the details concerning data collection, including how much and what type of data is required and when and how it should be collected. Exercising the scenario without any data collection plan and mechanism in place would simply yield a narrative with no output for

analytical use; thus, a great expenditure with very little return on investment (ROI). When developing the plan, consideration of the scenario and the requirements are important. Just as the scenario is traced back to the requirements, so, too, is the data collection plan to the scenario.

Key Players	Inputs	Outputs
Project Lead System Analyst	Detailed Requirements Metrics Scenario	Data Collection Plan

Table 25. Key Players, Inputs, and Outputs for the Define Data Collection Plan Sub-Step

(4) Verify & Validate (V&V) Scenario. The scenario, once established and finalized, must go through a final review to ensure to the customer that it is producible and relevant.

Key Players	Inputs	Outputs
Project Lead War fighter subject matter expert (SME)	Detailed Requirements Scenario	Perceived fitness and buy-in of the scenario for the project

Table 26. Key Players, Inputs, and Outputs for the Verify and Validate Scenario Sub-Step

c. *Define Detailed Schedule*

Given a well defined set of requirements and scenario to exercise, the next step for the Project Lead and Systems Engineer is to define a schedule to complete the analysis. Typically, the project is constrained to a specific time limit, and it is the job of the Project Lead and Systems Engineer to assess whether this time constraint can be met.

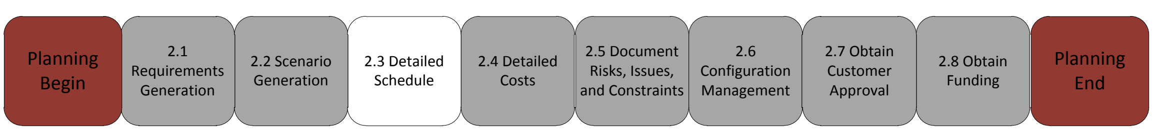

Figure 20. Define Detailed Schedule Step of the Planning Phase

Key Players	Inputs	Outputs
Project Lead Systems Engineer	Scenario Data Collection Plan	Detailed Schedule

Table 27. Key Players, Inputs, and Outputs for the Define Detailed Schedule Step

d. Define Costs

At this point in the project's cycle, the Project Lead and Systems Engineer will know the level of effort needed for the project. It is important to consider what the customer is willing to spend in direct contrast to what the team is able to accomplish. Should the costs of fulfilling the requirements as stated exceed the budgeted amount, revisiting the requirements and providing a reduction in scope will be necessary. Conversely, the Project Lead may opt to increase the fidelity of the analysis or perform the project below the budgeted amount should the estimate come in low.

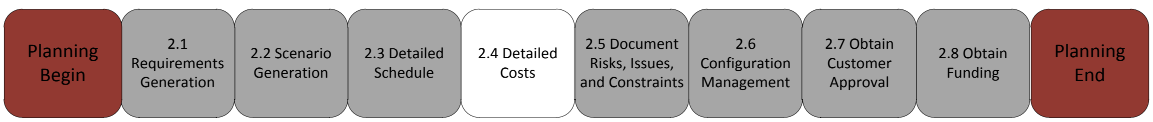

Figure 21. Define Costs Step of the Planning Phase

Key Players	Inputs	Outputs
Project Lead	Detailed Schedule	Project Budget

Table 28. Key Players, Inputs, and Outputs for the Define Costs Step

In any project, one must consider the customer's priorities. A fairly popular concept illustrated is the Project Management Triangle (see Figure 22), which addresses the relationship between cost, schedule, and performance (or quality). Should the project lack sufficient funding, then the Project Lead may opt to lengthen the time to complete. Should the project need to be completed within a small time frame, one can

expect higher costs due to the amount of manpower assigned to meet the timeline. Given the nature of the studies performed, the "fast and cheap" concept is not an option for our organization.

Figure 22. The Project Management Triangle (From: Wang 2010)

e. Document Risks, Issues & Constraints

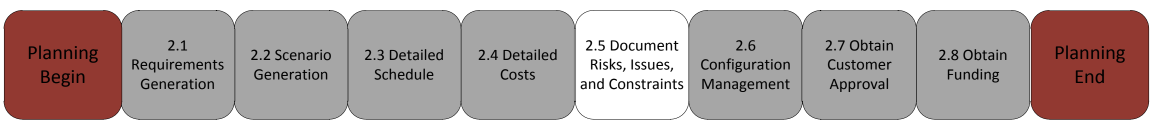

Figure 23. Document Risks, Issues & Constraints Step of the Planning Phase

Key Players	Inputs	Outputs
Project Lead Systems Engineer System Analyst Developers	All artifacts	Updated open statements of concern for stakeholders to consider

Table 29. Key Players, Inputs, and Outputs for the Document Risks, Issues & Constraints Step

f. Configuration Management

As in the previous phases, the Project Lead in conjunction with all involved members of the project need to exercise good configuration management practices in order to maintain the project documentation (living documents) for storage and future use.

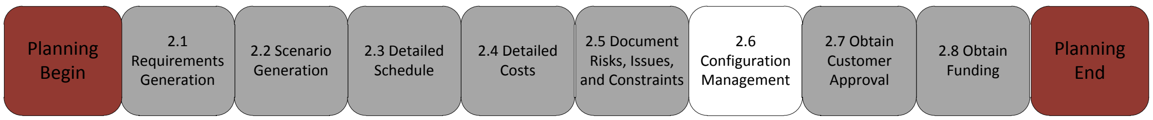

Figure 24. Configuration Management Step of the Planning Phase

Key Players	Inputs	Outputs
Project Lead Developers	All existing artifacts	Controlled method to preserve data

Table 30. Key Players, Inputs, and Outputs for the Configuration Management Step

g. Obtain Customer Approval

Upon completion of the preceding steps in this phase, it is important to review activities with the customer. In doing so, the customer gains a clear view of what the project is intended to do, how long the project will take, and is aware of concerns on behalf of the analysis team. The first progress review represents a significant milestone in the lifetime of the project, as it represents a go / no-go moment. Should any requirements be inappropriate or incomplete, correction of such at this juncture will significantly reduce any overhead or rework as opposed to catching and fixing later.

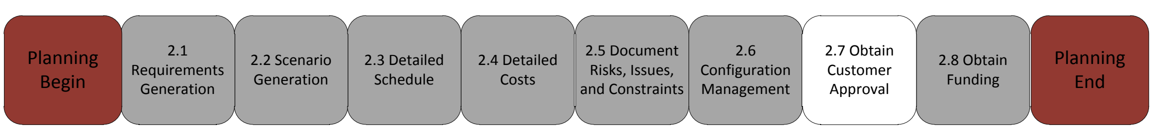

Figure 25. Obtain Customer Approval Step of the Planning Phase

Key Players	Inputs	Outputs
Customer Stakeholder Project Lead Systems Engineer Lead Analyst	All existing artifacts to date	Customer consent or need for rework.

Table 31. Key Players, Inputs, and Outputs for the Obtain Customer Approval Step

h. Obtain Funding

Upon completion of requirements, metrics, scenario definition, and traceability verification, which are all precursors to the actual execution, the remaining project funding should be in place. In the development of systems, this would mark Milestone B in product development. In the funding of systems, it is at this point in time that complete project funding has been secured.

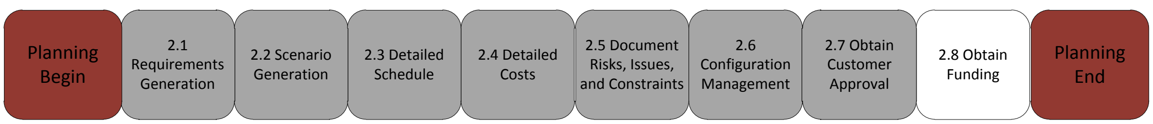

Figure 26. Obtain Funding Step of the Planning Phase

Key Players	Inputs	Outputs
Project Lead	Detailed Project Schedule Project Budget	Customer Funding

Table 32. Key Players, Inputs, and Outputs for the Obtain Funding Step

3. Execution Phase

The execution phase consists of steps which define the computing environment, acquire necessary assets (hardware, software, resources) to run the scenario, develop procedures for scenario execution, and finally review with the customer the scenario and execution at hand. At this point, analysis is yet to be performed.

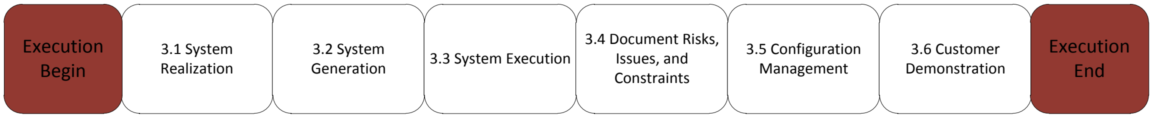

Figure 27. Execution Phase

Key Players	Inputs	Outputs
Developers Project Lead Project Analyst Supervisor Financial Manager Team Members Players	Scenario Funding	Implemented Scenario

Table 33. Key Players, Inputs, and Outputs for the Execution Phase

a. System Realization

The system realization step takes all work previously performed and begins to place it in action. This step includes identification of hardware, software, and network solutions and well as personnel resources.

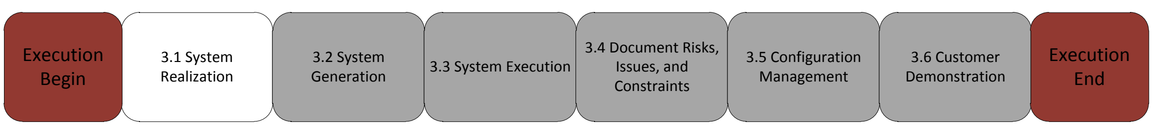

Figure 28. System Realization Step of the Execution Phase

Key Players	Inputs	Outputs
Developers Project Lead Project Analyst	Scenario Data Collection Plan	Physical System Personnel Assignments

Table 34. Key Players, Inputs, and Outputs for the System Realization Step

(1) Identify Hardware, Software, and Network Solutions. Upon obtaining customer approval, it is now the responsibility of the team to define what physical assets are necessary to execute the project. As with the search through existing scenarios, the team should look at the asset inventory which already exists. The team should take advantage of this and identify any lacking resource. This is one of the reasons that costs are broken into two sections. It is not until the requirements and scenario have been defined that the Project Lead will have a solid idea of the hardware, software, network, and personnel, resources which will be needed.

Key Players	Inputs	Outputs
Developer Project Lead	Scenario	Tangible needs list

Table 35. Key Players, Inputs, and Outputs for the Identify Hardware, Software, and Network Solutions Step

(2) Identify Project Resources. Given the development of project requirements, scenario, and hardware and software assets needed, the Project Lead and Supervisor have a relatively clear vision of the level of effort involved in the analysis. Furthermore, they have a view of what types of resources are needed, such as software engineers, analysts, network technicians, and statisticians. The supervisor is responsible for assuring availability of the human assets required for the project. By involving the supervisor, the Project Lead gains commitment from management that the project at hand shall be supported.

Key Players	Inputs	Outputs
Project Lead Supervisor	Scenario Hardware, Software and Network Resources	Staffing Management Commitment

Table 36. Key Players, Inputs, and Outputs for the Identify Project Resources Sub-Step

b. System Generation

The system generation step translates the storyboard scenario defined in previous steps into a software and hardware solution. Application of the functional decomposition at this step will allow the developers who are responsible for developing the simulated environment to establish it in a modular fashion in order to meet project demands.

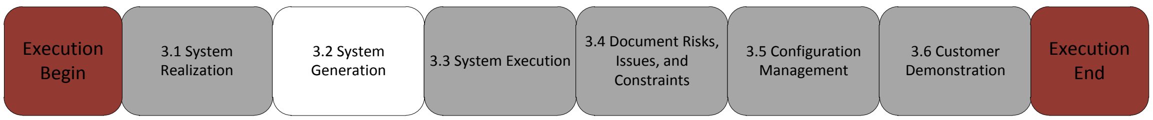

Figure 29. System Generation Step of the Execution Phase

Key Players	Inputs	Outputs
Project Lead Developers	Resource Identification	Hardened Resources Scenario Load

Table 37. Key Players, Inputs, and Outputs for the System Generation Step

(1) Acquire Identified Hardware, Software, and Network. Lead time is necessary to acquire the software and hardware assets identified. It is optimal to use this lead time in parallel with previous steps but is not always possible given that the simulation environment, which includes a list of physical assets involved in conducting the simulation as well as software to be installed to run the simulation, will not have been identified until the last minute. This step simply consists of ordering and obtaining all tangible assets for the project.

Key Players	Inputs	Outputs
Project Lead Financial Manager	Hardware, Software, Network Equipment Needs	Acquisition of Stated Assets

Table 38. Key Players, Inputs, and Outputs for the Acquire Identified Hardware, Software and Network Step

(2) Train Staff. The Project Lead must also assure that the staff has received relevant training on the assets used on the project. By not doing so, the setup and execution of the analyses will likely be error prone and could lead to negative results.

Key Players	Inputs	Outputs
Project Lead Project Analyst Team Members	All hardware and software resources	Knowledgeable staff

Table 39. Key Players, Inputs, and Outputs for the Train Staff Sub-Step

(3) Configure Environment. After obtaining the assets and training the staff, the environment must be established. This includes loading software on machines, documenting changes to be recorded in the configuration management system, baselining all machines for quick recovery should it be needed, and developing processes, policies, and procedures in order to conduct the analyses.

Key Players	Inputs	Outputs
Project Lead System Analyst Team Members	Hardware, Software, Network, and Human Resources	Operational Environment which is configuration managed and has appropriate documentation

Table 40. Key Players, Inputs, and Outputs for the Configure Environment Sub-Step

(4) Develop Procedures. While configuring the environment, the Systems Engineer should institute a systematic, disciplined approach, documenting every step taken, including steps which generate errors. In doing so, the project documentation will include a troubleshooting list. The procedures developed should include steps for installing and configuring needed software in addition to steps for running the software. This will be used by members who will be participating in the scenario’s execution.

Key Players	Inputs	Outputs
Team Members	Installations Configuration	Documentation of change control as well as process steps for execution

Table 41. Key Players, Inputs, and Outputs for the Develop Procedures Sub-Step

c. System Execution

The System Execution process, in theory, should be relatively straightforward provided ample consideration was given to the previous steps. Executing the environment consists of running the scenario and verifying that the data collected addresses the requirements and metrics.

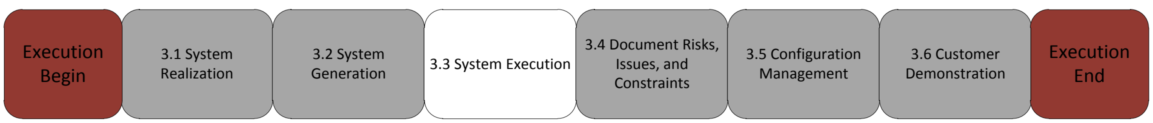

Figure 30. System Execution step of the Execution Phase

Key Players	Inputs	Outputs
Project Lead Project Analyst Players	Resources	Data Collection

Table 42. Key Players, Inputs, and Outputs for the System Execution Step

(1) Run Scenario(s). By executing in accordance with policies and procedures documented in the previous step the scenario running process should be straightforward. Duration depends on scenario timeline, number of humans in the loop and scenario iterations.

Key Players	Inputs	Outputs
Players Project Lead Project Analyst	Physical System Personnel Resources	Scenario Execution

Table 43. Key Players, Inputs, and Outputs for the Run Scenario(s) Sub-Step

(2) Verify Data Collection. It is recommended to verify data collection after an initial scenario run. This includes checking for the output data fields and verifying their application to the requirements and metrics, as well as considering the values being returned and whether or not they seem realistic. If the wrong values are being collected, the data collection plan should be cross referenced for completeness and the data collection tool configuration should be verified. Any unrealistic return values should be analyzed, leading to a review of input values, the impacts of any randomizer involved, and consideration to the standard deviation of outer bounds.

Key Players	Inputs	Outputs
Project Lead Project Analyst	Scenario Data	Information applicable to analyses

Table 44. Key Players, Inputs, and Outputs for the Verify Data Collection Sub-Step

When performing a data collection validation check, consider that the initial settings, such as the initial seed produced by a random number generator used may create extreme, yet valid results. Further iterations of the scenario are necessary until the analyst is satisfied that the results yielded are appropriate.

d. Document Risks, Issues, & Constraints

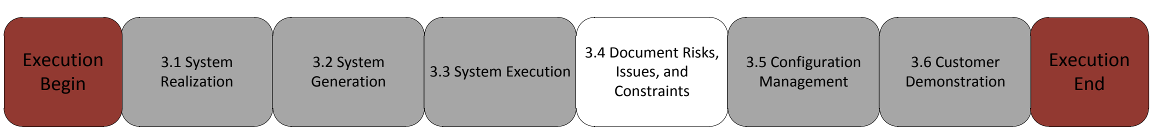

Figure 31. Document Risks, Issues & Constraints step of the Execution Phase

Key Players	Inputs	Outputs
All	All Phase Activities	Updated open statements of concern for stakeholders to consider

Table 45. Key Players, Inputs, and Outputs for the Document Risks, Issues & Constraints Step

e. Configuration Management

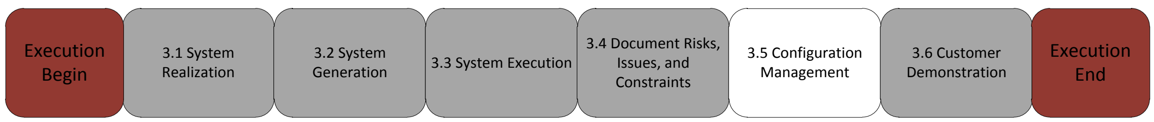

Figure 32. Configuration Management Step of the Execution Phase

Key Players	Inputs	Outputs
Project Lead Developers	Existing artifacts to date	Controlled method to preserve data

Table 46. Key Players, Inputs, and Outputs for the Configuration Management Step

f. Perform Customer Demonstration

The customer demonstration provides to the customer an overview of the scenario being executed and details of the data being collected. The customer should not expect any analyses to be performed at this point in time. The goal of this step is to assure that all considerations have been made regarding customer requirements, that the data being collected will be useful for analysis and that no scenario reworks, or data collection adjustments are necessary.

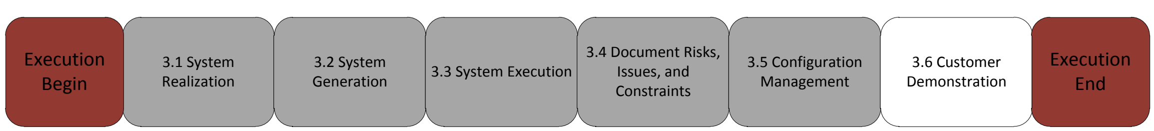

Figure 33. Perform Customer Demonstration Step of the Execution Phase

Key Players	Inputs	Outputs
Project Lead Project Analyst	Execution of a single scenario	Customer feedback before performing multiple iterations of the scenario

Table 47. Key Players, Inputs, and Outputs for the Perform Customer Demonstration Step

4. Analysis Phase

Analysis begins at the point of scenario creation and design. By doing so, the analyst has a good idea of what the initial scenario state is and what information can ultimately be derived from it. The main brunt of the task occurs during and after scenario runs. It is the analyst's job to receive and process information, turn it into useful data, perform analysis on the data, then format and report the results.

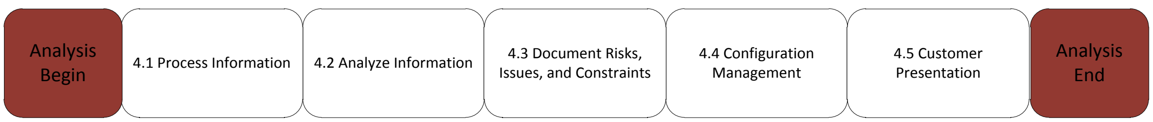

Figure 34. Analysis Phase

Key Players	Inputs	Outputs
Project Lead Project Analyst Developers	Data From Scenario Runs	Analyses

Table 48. Key Players, Inputs, and Outputs for the Analysis Phase

a. Process Information

There is a major distinction between information and data, as all things that are received are considered data while only the relevant items are further refined to become information. The amount of information available becomes significant as better data collection plans are developed and implemented. However, it is important to note that there may not be enough information based on the data provided, or when

information appears unreliable, the data collection must be expanded in order to investigate any dependencies which may be skewing the results.

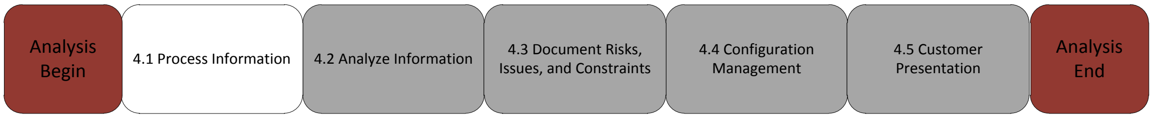

Figure 35. Process Information Step of the Analysis Phase

Key Players	Inputs	Outputs
Project Lead Project Analyst	Data Collected	Determination of utility of data collected

Table 49. Key Players, Inputs, and Outputs for the Process Information Step

b. Analyze Information

Once the correct amount and fidelity of information has been collected, the analyst performs the appropriate analyses. Methods of analysis are beyond the scope of this document and therefore shall not be discussed.

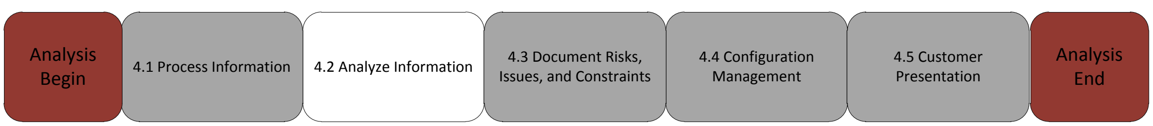

Figure 36. Analyze Information Step of the Analysis Phase

Key Players	Inputs	Outputs
Project Analyst	Information	Analytical Results

Table 50. Key Players, Inputs, and Outputs for the Analyze Information step

c. Document Risks, Issues, Constraints

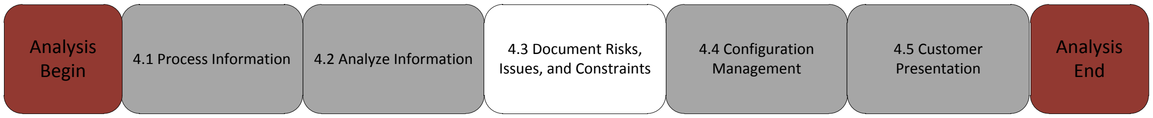

Figure 37. Document Risks, Issues & Constraints Step for the Analysis Phase

Key Players	Inputs	Outputs
All	All phase activities	Updated open statements of concern for stakeholders to consider

Table 51. Key Players, Inputs, and Outputs for the Document Risks, Issues & Constraints Step

d. Configuration Management

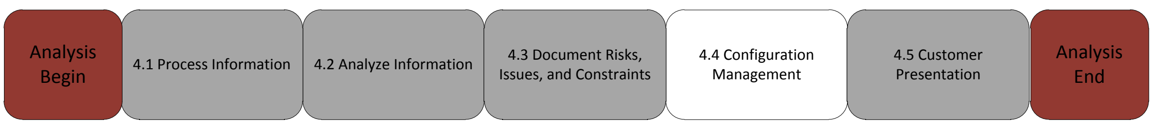

Figure 38. Configuration Management step of the Analysis Phase

Key Players	Inputs	Outputs
Project Lead Developers	All existing artifacts	Controlled method to preserve data

Table 52. Key Players, Inputs, and Outputs for the Configuration Management Step

d. Customer Presentation

When appropriate, the analyst shall create visual representations as well as written reports, spreadsheets, and other pertinent documents on the results. It is recommended that the Project Lead and Systems Engineer be present during reporting as stakeholders may have questions regarding the means by which results were derived.

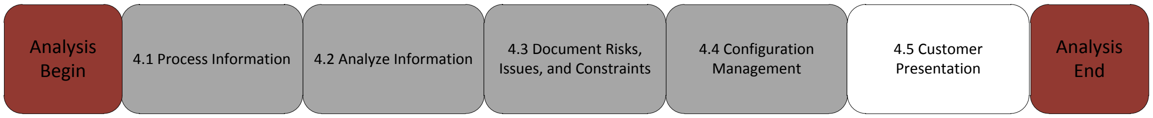

Figure 39. Customer Presentation Step of the Analysis Phase

Key Players	Inputs	Outputs
Project Lead Project Analyst	All Configuration Managed Data	Customer Presentation

Table 53. Key Players, Inputs, and Outputs for the Customer Presentation Step

III. SUMMARY

In summary, Figure 40 presents the current Architectural process proposed to address the need for a standardized process for performing analysis within the Operational Simulation & Analysis branch. Sources of information referenced in the development of this process range from publications related to the discipline of System's Engineering, Software Engineering, and Operations Research, in addition to personal experience from over a decade in this specific field which has served to provide the majority of influence and contribution to its creation.

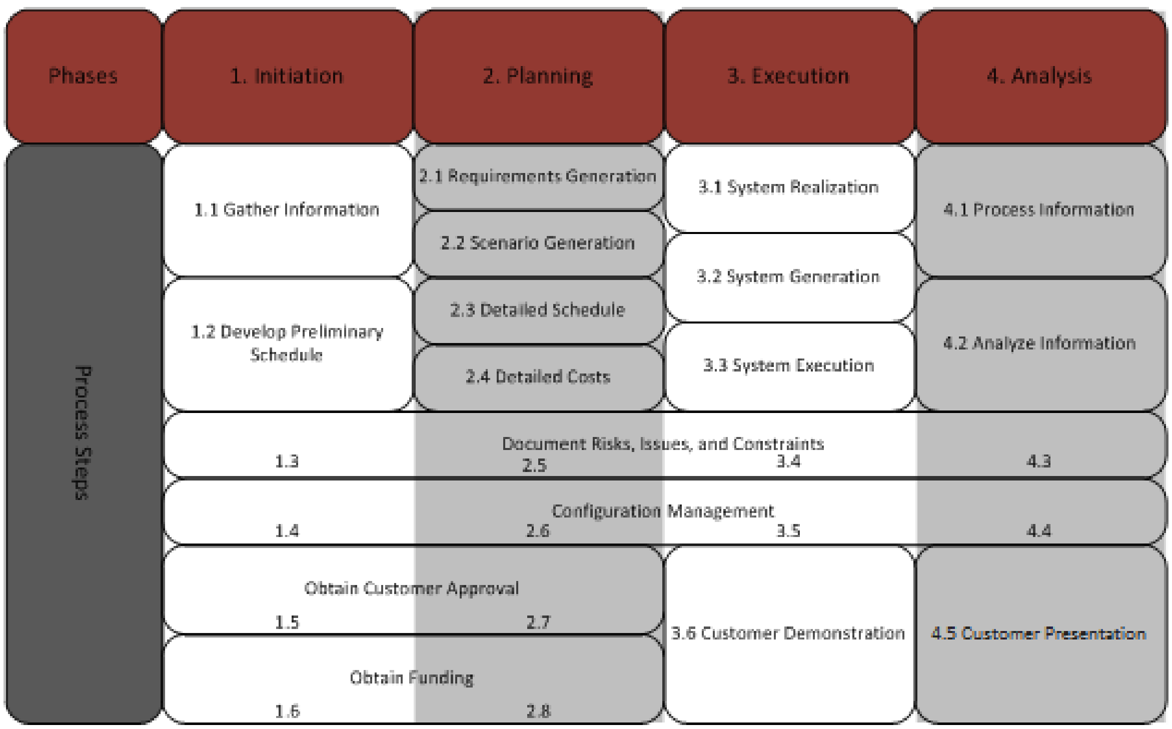

Figure 40. Architectural Process

Having such a plan is important to the OS&A branch and ARDEC as a whole because it documents decisions, facilitates communication among stakeholders, and maintains a record of scope, cost, and schedule baselines. By instituting a standardized process, the OS&A branch would ensure that results based on the Analysis Project Plan

are reusable, allow for configuration management, better management of overall resources, and better validation and verification.

The process is presented in four phases, Initiation, Planning, Execution, and Analysis. Within each phase are sequential steps. The project lead has the flexibility to add or omit steps as required by the particular project and the OS&A branch as a whole is requested to contribute suggestions to this process over time in order to provide the best process possible for the purposes of performing analysis through simulation.

The key aspects in the proposed process consist of the following:

Process Flexibility: Adapting to changes as they become prevalent in addition to incorporating emerging best business practices ensures that the process will continue to benefit the project lead and that the project lead, in turn, will embrace the process.

Emphasis on Deriving Level of Effort / Aggregation in the Initiation Phase: A shortcoming observed through personal observation of business processes indicates that the current business model frequently underestimates scope, time, and cost considerations which ultimately lead to overruns. In establishing the level of effort required for project success through determining aggregation level of the analyses prior to executing a systems approach, the project lead gains the ability to verify that the customer’s need is in alignment with the amount of funding and time the customer is willing to commit.

The Planning Phase marks the kickoff of the Systems Approach: During the Planning Phase the discipline of the systems approach is executed. The outputs of the Initiation Phase provide the basis for the Planning phase such that the project lead has identified the customers and stakeholders from which to conduct requirements elicitation, then perform prioritization, decomposition, and metric development activities. At the completion of these activities reliable estimates of time and cost are understood, presented, and resolved through the customer.

Establish Retainer Funding to Determine Project Feasibility: Through establishing a dual payment system, or retainer funding scheme, both the customer and the Operational Simulation & Analysis branch are ensured the highest degree of success with minimal waste in terms of cost and time. The intent of the retainer funding is to allow the

project lead to conduct the Project Initiation and Planning phases and determine if proceeding to the Execution and Analysis phases as prescribed are feasible. As an illustration, consider the activities conducted when an individual purchases a home. In the majority of cases, prospective buyers prefer to make the investment in a home inspection in order to decide whether to proceed with the purchase, renegotiate terms, or terminate the contract. The prospective buyer understands that this is a non-refundable investment but finds the cost of the investment preferable to the potential consequence of not having the inspection done at all.

Iterative Risk Management: A continual feedback loop between the project lead, customer, and stakeholder ensure the customer's expectations are being met while unexpected consequences that arise throughout the lifetime of the project are communicated between all parties involved. Risk management assures that all parties have collectively participated in the resolution of unforeseen circumstances which may otherwise halt project execution and impair overall project success.

Iterative Configuration Management: Adopting and adhering to a configuration management scheme provide a benefit to the entire OS&A branch and, in turn, future customers through the practice of reuse. The ability to consult an archive of previous exercises for reuse in a current project will aid in minimizing cost and schedule requirements.

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IV. CONCLUSION

In conclusion, past experience has shown that adopting any structure as opposed to operating in an ad hoc fashion is beneficial to branch success. This thesis has presented a process with specific application to the field of analyses through modeling and simulation. Furthermore, this thesis has also defined the roles and described activities key players enact throughout its progression. By establishing a flexible process where communication of the problem is precise, the magnitude of the solution is relevant and reliable, and the tools and personnel to execute the analysis are employed at the right times, the Operational Simulation and Analysis branch will continue to establish their role in ARDEC's overall objective striving to support the RDECOM mission of getting the right technology to the right place, at the right time for the War fighter (U.S. Army ARDEC 2001).

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